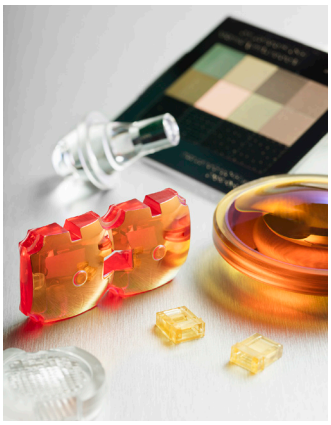
Coating Plastic Substrates

Cicely Rathmell

AccuCoat inc.
Coatings for Optics



Did you know that more than half the substrates we coat are plastic? Often chosen for their low weight or durability, plastics are being used in an increasing number of medical, imaging, military, and virtual reality applications. Coating on plastic requires specialized cleaning, handling, and deposition processes in order to match the optical performance and durability possible on glass – and not everyone can do it.

In this technical note, we share how AccuCoat has overcome these challenges, and some of the surprising MIL-SPEC tests we've passed. We'll also explore the many coatings we can offer in the transition from glass to plastic. We'll also share case studies of some successful projects, from laser sighting optics and mylar sheets to hot mirrors for virtual reality.

Why Choose Plastic Optics?

Weight, cost, and durability are the three most common reasons to design an optic in plastic. Plastic is 1/10th the weight of glass, yet offers comparable transmittance. It can also be inexpensively molded in volume, often in configurations that simplify mounting and system assembly. Though more sensitive to scratching, plastic offers greater impact resistance than glass, and tends to break into fewer, less dangerous fragments rather than splintering.

We frequently work with customers who want to transition a design from glass to plastic due to damage or weight, but without compromising optical performance or the ability to meet a specific MIL-SPEC standard. The conditions that must be met can be very severe – including extreme temperature cycling, shock, and chemical resistance to materials like insect repellent, antifreeze, and rifle bore cleaning compound. In new optical designs, the basic needs are the same – a coating that performs well optically and is durable.

AccuCoat has spent nearly 20 years developing processes specifically for coating on a wide range of

Case Study: Laser Sighting

The OEM that came to us had been using a small triangular coated glass window at the end of a gunsight, but was seeing frequent cracking in the field due to the rough handling. They needed a drop-in replacement window in plastic that met both the needed optical performance and all environmental requirements (including chemical exposure and severe temperature cycling). Of the three suppliers who provided prototype optics in plastic, AccuCoat was the only one to pass the full suite of environmental tests.

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Coating Options on Plastic Optics

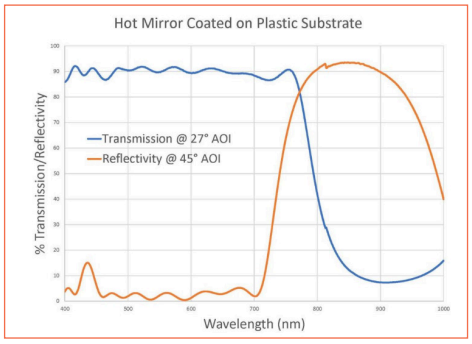
While standard and wide-angle anti-reflection (AR) coatings are no doubt the most popular request we get on plastic optics, we routinely provide many other coating types, including mirrors, beam-splitters, and filters. In fact, we can offer comparable optical performance to the same coating on glass in many cases, particularly in the visible wavelength range.

AR Coatings

An air-plastic interface reflects approximately 4% of light, which can easily be reduced to below 0.5% with an AR coating, and even down to 0.25% at a single wavelength on a high quality substrate like Zeonex®. Wide angle AR coatings are often needed for lenses and elements with a high degree of curvature; we created a 1064 nm AR coating for one military customer that performed at up to 45° AOI.

Mirror Coatings

We have developed robust processes to apply both dielectric and metal mirror coatings to plastic substrates, including silver (Ag), gold (Au), and aluminum (Al). While many vendors have issues with adhesion when coating metal on plastic, we understand how to adapt our process to the specific substrate type to achieve adhesion that easily passes a standard tape test and meets the same optical specifications as on glass. We've even been able to adapt our processes to apply ITO coatings to plastic substrates with very good performance.



Case Study: AR coated mylar sheets

The laser instrumentation and diagnostics markets have a need for very thin (2 mil) mylar coated sheets. By adjusting coating processes and developing custom tooling to accommodate the thin, flexible material, current coating technology can achieve a uniform AR V-coat across the sheet without compromising pliability; the coated sheet can even be rolled up and flexed without cracking or crazing the coating.

Filter Coatings

We can successfully apply many filter coatings to plastic substrates, including some quite challenging curves. Broadband filters, longpass filters, and hot mirrors are all possible with somewhat less edge steepness than on glass – even simple cold mirrors can be done.

Beamsplitters

Our beamsplitter coating offerings include standard splitting ratios from 50/50 to 70/30, as well as polarizing beamsplitters with up to a 300:1 extinction ratio. We routinely work hand-in-hand with vendors to create finished plastic beamsplitter cubes: the prisms are shipped to us to apply beamsplitting coatings, after which the vendor assembles the prisms into a cube at their facility for final AR coating at AccuCoat. The beamsplitter deposition processes we've developed are designed to maintain prism flatness without compromising optical performance, and are gentle enough to enable the application of AR coatings to assembled optics.

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The Challenges of Coating Plastics

Deposition of optical coatings on plastics is not nearly as straightforward as on glass, and requires specialized processes to ensure adequate adhesion. Without these, coated plastic optics are prone to peeling and flaking, particularly when subjected to harsh environmental conditions. Coating parameters must also be modified to obtain equivalent optical performance, as plastic is unable to withstand the extended high temperature exposure used during a typical glass coating run.

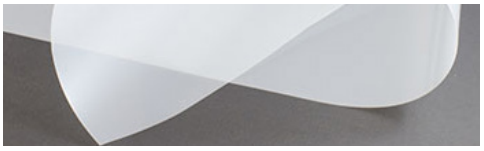
At AccuCoat, we've put a tremendous amount of effort into process development for plastic optics – from substrate preparation to coating – as this is the key to producing durable high optical quality coated optics. Through nearly 20 years of experience on 1000+ projects, we've optimized our processes to achieve a high degree of adhesion and excellent optical performance on a variety of plastic materials and form factors.

Coating Deposition

Most plastics simply can't withstand the typical 250°C coating temperatures used for glass without warping or deformation, so we've redesigned our deposition processes to work at lower temperatures for plastics. Careful customization of the coating parameters, materials, and layer design not only allows us to control the heating of the substrate to prevent damage, but also enables us to deposit more layers to achieve more challenging spectral profiles. We've learned that many of the coating parameters are substrate specific, and thus we draw on our experience to fine-tune the design and deposition controls for each unique combination of coating, substrate material, and form factor.

Cleaning & Handling

Creating a good quality coated optic from a plastic substrate depends heavily on proper cleaning and handling of the parts prior to deposition. Many plastics scratch very easily as compared to glass, and without proper cleaning, it's impossible to get good coatings that adhere well. AccuCoat has invested significant time and effort into developing a combination of ultrasonic and hand cleaning methods for plastic optics, and into learning the chemistry that works best for each plastic type.



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Most lenses, prisms, and windows are cleaned ultrasonically using a few select chemicals and surfactants, followed by a hot rinse in deionized water, and a hot air dry to avoid damage. Our experience has taught us which detergent solutions are needed to correct specific cleaning or adhesion issues, and we work with different detergent vendors to find the best solution for a particular project. Sheet materials require their own unique handling methods to avoid damage and ensure cleanliness prior to coating, as well as specialized fixtures.

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Meeting MIL-SPEC

Many optical parts are required to meet a specific MIL-SPEC or similar set of environmental test requirements to guarantee adequate performance and reliability for a specific application. Typical tests include abrasion, chemical resistance, humidity and multiday temperature cycling.

Ability to withstand abrasion and chemicals depends primarily on applying a durable final coating layer; we typically use oxides for this purpose, which can handle most chemical tests. Severe temperature cycling, however, can be more challenging. Plastic substrates expand very differently from typical coating materials, increasing the stress on the interface. This makes it all the more important to ensure that parts are extremely clean, as any type of contamination can result in adhesion failure.

At AccuCoat, we have adapted our coating materials and layer designs to minimize stress on the substrate/coating interface, and apply the same level of attention to detail in our cleaning processes. We fine-tune all aspects of the coating process for each project, carefully considering the interplay of substrate material, form factor, and optical specifications to meet the environmental test requirements.

This is key to providing quality coated optics, as a coating which passes a specific environmental test on one substrate is not guaranteed to pass on another substrate simply by using the same process, nor can every coating necessarily pass all tests. At AccuCoat, we carefully consider the MIL-SPEC or other environmental requirements that must be met in volume, even when coating prototype parts. This ensures that the optical performance delivered initially can still be met once a product scales to volume, and reduces program management risk for our customers.

Our standard and custom coatings have been shown to pass a variety of challenging MIL-SPEC and ISO specifications, including tests such as those shown below.

Sample Coating Durability Tests

Note: Not all tests will be passed by all coatings on all substrates. Please consult an AccuCoat engineer to discuss your specific requirements.

Operating environment tests:
- 24 hour humidity exposure
- 10 day humidity exposure
- Temperature cycling: -62 °C to +85 °C
- Temperature shock: +23°C/-57°C/+71°C/+23°C
- Moderate abrasion
- Adhesion
- Salt solubility (not appropriate for metals)
- Salt Fog (not appropriate for metals)

Chemical exposure tests:
- Insect Repellent
- Penetrating oil
- Antifreeze
- Carbon removing compound
- Lubricating oil
- Rifle bore cleaning compound
- Vacuum pump oil

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> "When it comes to coating, 50% of your success lies in the coating design – the other 50% comes from your ability to correctly clean a part in a cost-effective way without damaging it. Cleaning is half the battle, so we really work hard on our ability to clean optics."
>
> - Paul Meier-Wang, President

Make AccuCoat your partner for coated plastic or polymer optics

Many variables influence adhesion of a coating to a plastic substrate, from the coating design, process and temperature to the cleanliness of the substrate (and the substrate material itself). Changing even one of these variables can significantly impact a coated plastic optic's ability to pass MIL-SPEC or other environmental testing – putting your project schedule or product launch at risk.

At AccuCoat, we've put in the time to really understand the interplay of these various factors and adapt our processes accordingly. We have developed specialized cleaning, handling, and deposition processes to meet even the most demanding MIL-SPEC standards. In fact, we can match the performance of many optical coatings available on glass, from AR and mirror coatings to beamsplitters and filters. We can work with you to create a drop-in replacement for a glass component to reduce weight, cut cost, or allay safety issues associated with cracking and splintering in the field. We look forward to being your preferred partner for coating plastic optics.

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